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Situation modeling of regional development in the Republic of Kazakhstan

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Abstract

The methodology of situation modeling was based on the application of fuzzy cognitive maps, indistinct regional data and indistinct time horizon. Based on indistinct number of involved concepts, the model enables users to create their own situations with fuzzy quantity of available concepts including both the existing and the added ones. The added concepts are characterized by the set properties and database related to no less than three fuzzy time horizons. The number of set impulses is fuzzy as well. Cognitive map training was based on the artificial intelligence element – the active Hebb learning rule. The impact of concepts was defined in the course of training. Fine adjustment of the fuzzy cognitive map was achieved by changing the training order using a rank scale and Saati's sorting algorithm. The developed computer software was used in simulation modeling of regional socio-economic processes related to the project aiming at tourism development of the Alacol Lake in Almaty region. Research results are shown in the form of a fuzzy cognitive map reflecting internal and external relations within the region, graphs reflecting socio-economic development and the Bossel criterion. Simulation of allocations had a positive effect: GRP (Gross Regional Product) growth along with increase in employment and environmental improvement. The proposed approach provides a tool for forecasting of regional development and solution of different regional problems. This approach can be used with regard to any administrative-territorial entity, provided relevant statistical data.

Keywords*:* Situation Modeling, Fuzzy Cognitive Map, Cybernetic Tools, Regional Development Processes

Introduction

Presently, the industrial and innovative development of Kazakhstan demands innovative models and scenarios of efficient regional economic management aimed at problem prevention. Simulation modeling and problem analysis combined with instrumental search for the ways of rapid and effective restoration of regional sustainable development are key prerequisites for improving the efficiency of regional management.

The world economic crisis, instability of currency exchange rates and related changes in regional economic processes determine new requirements of simulation modeling: modeling and analysis of various managerial measures and their consequences along with preventing problems (crises) in the Kazakh regions and in the entire country. In order to formalize such situations, new theories, relevant models and mathematical apparatus have to be created. There is an urgent need for tools used in taking various managerial decisions in terms of planning and management of regional socio-economic processes along with comprehensive analysis of regional development. Such models can be based not only on statistical data, but also on supplementary information obtained from a person engaged in problem solution.

In 2010-2013, the General Area Development Scheme of the Republic of Kazakhstan (GADS RK) was developed with the view of improving living standards, providing sustainable regional development of Kazakhstan in the context of world economic integration and globalization. That was an urban planning project aimed at the long-term spatial development, including the system of rational organization of the country's territory aimed at gaining territorial competitive advantages and sustainable development of the entire country (hereinafter referred to as the General Scheme) (Zabolotski, Tikhonin and Polyakova, 2007).

The General Scheme contained substantiated recommendations related to regional migration and allocation of the country's economic potential for taking balanced decisions by the central and local executive authorities, as well for orientation of business entities at the most beneficial location of investment. Moreover, the General Scheme was the basis for further development of urban planning documentation, according to its basic provisions: comprehensive schemes of inter-regional, regional and district planning, general plans of settlements, and detailed planning projects.

In order to obtain the information on the basic provisions of the General Scheme in terms of the Kazakh regions, specialists developed a unified software package – the Analytical System of the General Area Development Scheme of the Republic of Kazakhstan (hereinafter referred to as the AS GADS). The System included a number of subsystems, such as the software module for predicting economic indicators, the module used for comprehensive evaluation of area potential, the module used for spatial data visualization, as well as the module providing access to the external information systems. All the information obtained from different modules is stored in a single data warehouse. AS GADS is a decision support system used in the spatial organization of areas; this system is based on using contemporary technologies of data collection, processing, analysis and storage as well as on monitoring, modeling and forecasting.

Certainly, AS GADS is focused mainly on modeling urban planning decisions during spatial area planning. Therefore, this system demands permanent update of database and software in order to provide in-depth study, analysis and managerial decisions related to socio-economic development of regions in different situations.

The above objectives required solution of the following problems:

- development of the situation modeling methodology with the view of studying regional socio-economic data to develop software for the intelligent system of managerial decision-making;
- cognitive structuration and situation modeling (by the examples of several regions), with the view of comparing the achieved results with the previously occurred situations.

This paper was based on the following:

- Macroeconomic indicators of long-term forecast in the development of AS GADS;
- Technique aiming at integrated planning assessment;
- Regional data provided by Regional Statistics Departments;
- Official statistical data of central and local executive authorities;
- Expert assessments provided by the involved professionals and AS GADS developers.

This model can be used by public servants in the elaboration of relevant strategies and regional development programs as well as by experts, analysts and GADS developers.

Effective solution of this problem is achieved through the intuition of decision-makers, opinions expressed by experts and analysts along with modern technologies aimed at intelligent support of decision-making and the fuzzy sets theory.

GADS RK provides area development including strategic decision-making, which ensures effective functioning of areas in the long term.

Modern development of the regional socio-economic systems, changes in the activity spheres and volumes, competences and responsibilities of the regional authorities require a clear, well-designed and well-founded regional policy. Consistent and holistic view of regional situations is an indispensable component of effective managerial decisions.

Wrong strategic solutions cause violation of sustainable development principles, which can lead to economic breakdown, environmental social degradation.

Today, situation modeling presents one of the most effective tools used to analyze the development of critical situations, and functioning of sophisticated organizational and technical systems. Situation modeling allows solving various problems, such as monitoring, analysis of situational development trends, forecasting and modeling the future system behavior of strategic or operational programs, investment or implementation of other projects.

Elaboration of area development strategy is a complex and resource-intensive process being carried out under the conflict among engaged persons. In this regard, elaboration of the scientifically grounded approach to administrative decisions related to the implementation of area development plans requires finding technologies that could provide formation and analysis of various alternative options as well as their efficiency assessment (Plotinsky, 2001).

The Modern Approaches to the Regional Development Modeling

Any region is a dynamic complex system, which includes natural, planned and social subsystems. The information, which describes functioning of these subsystems is usually bulky, heterogeneous, and often has no quantitative interpretation. Modeling of such systems, visualization of qualitative transitions of their elements and the entire systems form one state into another is quite difficult. Classical approaches of applied mathematics are not always suitable for modeling the state of such complex systems. Traditional methods are not suitable for solving such problems due to their axiomatics. Therefore, it is expedient to use fuzzy analysis and scenario modeling for data processing (Roberts, 1986) and in the development of relevant strategies. Today, fuzzy game theory, fuzzy sets, and fuzzy cognitive maps become popular. The cognitive approach proposed by Axelrod (1976) and developed both in theoretical and applied aspects is applied for modeling of semi-structured systems. This approach is oriented at intensification of the intellectual processes of persons responsible for decision-making process assisting them in fixing their vision of a certain problem in the form of a formal model. Such model is displayed by a cognitive map describing a number of ideas (factors) related to a certain situation along with the established set of cause-and-effect relations.

Its application to social, biological and ecological tasks and the description of impulse processes used in forecasting development of various situations is described in detail in the well-known research paper by Roberts (1986).

Classical cognitive models are developed into fuzzy cognitive models, which take into account the fact that mutual impact of factors caused by the presence of cause-and-effect relations can have various intensity and herewith the intensity of any impact can change with time. Cognitive science was further developed by Bartolomeo Cosco who invented fuzzy cognitive maps (hereinafter referred to as FCMs), which allows representation in the form of a weighted graph, currently used in most dynamic modeling systems (Koulouriotis, Diakoulakis and Emiris 2001b).

Presently, cognitive modeling methods are widely used to study complex semi-structured systems. In this regard, one should mention research papers by Gorelova (2012), Zabolotski (2008), Evstegneyev (2003), Kulinich (2002), Maksimov (1998), Sadovnikova (2012) and other scholars.

This approach is widely used by foreign researchers, such as Busemeyer (1993), Roberts (1986), Carlsson (2005), Salvucci (2003), Calais (2008), Cole (2000), Dounali (2015), Glykas

(2010), Koulouriotis (2001), Maksimov (1998), Oja (1991), Hebb (1949), Stylios (1995), Groumpos (2004), Papageorgiou (2004).

The analysis of research papers shows that studies are focused on the formulation of managerial decisions and forecasting the development of social and economic systems, in particular, development models of different Russian regions, such as Tyumen and Rostov regions, Dagestan Republic etc.

Parygin, Sadovnikova and Zhidkov focused on territorial planning upon the scenario forecasting method and considered general issues of using simulation modeling for assessing environmental and economic effectiveness of urban planning projects (Plotinsky, 2001). Prangishvili considered the effectiveness of complex system management (Roberts, 1986).

Avdeev, Kovrik and Makarenko described the application of cognitive modeling in managing semi-structured systems (situations) and identified management problems, which demanded solutions based on cognitive modeling (Avdeeva, Kovriga and Makarenko, 2006).

The papers (Plotinsky, 2001; Sadovnikova, 2011; Sadovnikova et al., 2014; Sadovnikova and Zhidkova, 2012; Salvucci and Lee, 2003) provided analysis of using cognitive method in solving semi-structured problems, as well as the principles of fuzzy cognitive model building.

The methodology aimed at building cognitive maps is well described in a number of papers (Axelrod, 1976; Maikel León et al., 2010; Maksimov, Kornouwenko and Kachaev, 1998; Oja and Ogawa, 1991; Papageorgiou et al., 2004; Papageorgiou and Groumpos, 2005; Papageorgiou and Groumpos, 2004; Papageorgiou et al., 2013; Papageorgiou et al., 2004; Papageorgiou, Oikonomou and Kannappan, 2012; Papageorgiou et al., 2003; Papageorgiou, Stylios and Groumpos, 2002; Papageorgiou, Stylios and Groumpos, 2004; Papageorgiou, Stylios and Groumpos, 2003; Papageprgiou and Salmeron, 2011; Parygin, Sadovnikova and Zhidkov, 2012; Plotinsky, 2001; Prangishvili, 2005; Roberts, 1986; Saati, 1993; Sadovnikova, 2015; Sadovnikova, 2011; Sadovnikova et al., 2014; Sadovnikova and Zhidkova, 2012; Salvucci and Lee, 2003); it is based on building the situation model reflecting a person's knowledge of the regularities describing the analyzed situation. Cognitive maps provide the possibility to track interconnections between the future, the present and the past of the studied process (Roberts, 1986).

FCM is an effective tool and a promising technique of situation modeling that shows relations between completely different concepts, processes and parameters. FCM is flexible in terms of system engineering, modeling and control. FCM is applied to study the most complex problems and systems.

FCMs have the following advantages:

- no need to strictly adhere to the number of parameters and regular relations between them (formulas, graphs and other relations of mutual influence);
- visualization of the modeled subject area within the cognitive map;
- informativeness and simplicity of achieved results.

The mathematical model suggested by Silov (1995) is considered one of the most common models used to build FCMs. The values of concepts in this model are changing (Avdeeva, Kovriga and Makarenko, 2006). The FCM based on this mathematical model can be expressed as an incident matrix indicating the impact of one concept on another at the row and column intersection. The direction of impact is determined at the level of building the cognitive map where one needs to find out which concept is the cause and which presents the effect. The model suggested by Silov has been widely used in the computer system 'Kanva' designed to provide conceptual modeling of unstructured situations (Maikel León et al., 2010).

Alternative investigation methods are presented in the works by Bossel (2010).

Sadovnikova (2011) used Bossel's method for building cognitive maps and evaluation of sustainable urban development. Explanations were given to basic reference points and data structuring methodology by Bossel (2010). The model was built upon the list, groups, influencing factors and initial trends set by experts for each factor.

Paired comparison was used to develop the method of job interferences related to cognitive model factors as well as the algorithm to implement this method in the software package.

Forecasting system self-development was carried out through factor values provided the absence of external control actions. Solutions were also found by using impulses in the groups of factors for modeling the scenario of system development. 'Guidelines' for every group of factors were determined upon the obtained values.

Scenarios were assessed by the introduction of two coefficients – area (viability) and form (balance). Comparing these coefficients, one can assess their effectiveness and choose the most appropriate among them. The study provided formulas for their calculation and considered relevant calculation example.

The authors (Douali et al., 2015; Koulouriotis, Diakoulakis and Emiris, 2001b; Maksimov, Kornouwenko and Kachaev, 1998; Papageorgiou et al., 2004; Papageorgiou and Groumpos, 2005; Papageorgiou and Groumpos, 2004; Papageorgiou et al., 2013; Papageorgiou et al., 2004; Papageorgiou, Oikonomou and Kannappan, 2012; Papageorgiou et al., 2003; Papageorgiou, Stylios and Groumpos, 2002; Papageorgiou, Stylios and Groumpos, 2004; Papageorgiou, Stylios and Groumpos, 2003; Papageprgiou and Salmeron, 2011) used the Hebb learning rule (1949) of neural network training to correct expert perceptions. The obtained results were compared with the laboratory test results related to the hydraulic model of uninterrupted water supply management. FCM fine adjustment is achieved by changing the learning order set by the experts (Papageorgiou and Groumpos, 2005). FCMs can be a useful instrument for forming and re-confirming the hypothesis of functioning of the studied object considered as a complex system. In order to understand and to analyze the behavior of complex systems, one should construct a structural diagram of cause-and-effect relations.

Methodology

Despite vast experience of urban planning, many problems cannot be solved at once. Primarily, these are the problems related to coordination of objectives and their alignment with general goals of territorial planning.

The original approach provided in this research will allow making forecasts of the Kazakh regional development during occurrence and decurrence (elimination of negative factors and implementation of the positive ones) of various situations on a regional scale.

The situation is understood as making different urban planning decisions: construction of roads, water reservoirs, agricultural complexes and other facilities related to urban planning, as well as economic, social and ecological indicators resulting from their implementation. In this respect, research subject is determined as one of the Kazakh regions (oblasts). Overall, this approach may be used for any object of administrative-territorial entity provided statistical data related to the studied period.

The forecast period is fuzzy and has different features in different situations. For example, the situation related to construction of water reservoirs, power plants, and other large facilities may last twelve years or longer, however some situations may occur and could be dealt with in a month.

Regional development models present a complex system where the impact of certain factors on other factors is realized through complex cause-and-effect chains between these factors. The use of cognitive maps simplifies the study of the system's structural properties. Analyzing paths of the cognitive map provides the possibility to determine and to understand cause-and-effect chains between factors that influence regional development, and, if necessary, to break links or to add new links, to neutralize certain factors or to introduce new ones, i.e. to rebuild the structure of the cognitive model.

Generally, situation modeling and administrative decision-making in the context of regional development processes consists of six main stages:

1) Selection of indicators related to public authorities (data provided by local executive authorities, key provisions of the General Scheme, data provided by the central authorized body for statistics) to be used for describing current situation in a certain region. Every indicative figure presents either the official data provided by authorized state bodies or parameters, which calculation methodology is approved by authorized state body or well-known international statistic mechanisms, such as ‘Gini index’, ‘Human development index’ etc. 45 local and central state bodies of Kazakhstan were involved in the selection of indicative and negotiations.

The first stage provided the following:

- list of primary indicative figures;
- formulas, algorithms and methods used to calculate the required indicators;
- informal description of modeling objects indicating simulation purposes and certain aspects related to functioning of modeling objects to be studied in the situational model;
- grouping of indicators by industries, regions, by Bossel (2010) and by subsystem (social, economic and ecological state);
- impact (positive or negative) of indicators on the modeling situation;

2) Splitting all difficult problems into simple tasks, stages, situations, selection of indicators to formulate the problem; solving the prototypes of possible problems (situations), and the analysis of results. As regards situation modeling of certain regional problems, it is difficult or almost impossible to find statistical data, analytic description and relationship between input and output parameters of these problems. In the end, one has to use subjective models based on external information processed through logic, reasoning, intuition and heuristics. In this case, such problems are split into smaller known problems by means of algorithmization;

3) Formulation of goals and objectives, selection of criteria for modeling the state of solving regional problems. Developers solve these problems through the involvement of regional representatives for the creation of impulses related to indicative data in situation modelling and during the selection of impulses to return the region back to the to the sustainable development trends, described in the Main Provisions of the General Scheme.

4) Development and implementation of alternative approaches (decision-making options pursuant to Article 3);

5) Analysis of alternatives and assessment of available options;

6) Selection of one efficient solution with the highest coefficient of vitality and balance.

Each problem is solved by using the integrative method and cognitive maps by means of intuition and mild reasoning.

In this paper, building of cognitive maps includes the following stages:

- Determination of ways and means to describe the states or values of relevant concepts (data normalization – bringing the initial value of the concept to a normalized value in the range 0-1);
- Definition of formulas and algorithms describing mutual influence of concepts, definition of the cause-and-effect relationship between the concepts;
- Building the hierarchical structure of concepts pursuant to guidelines, subsystems etc.

Cognitive maps may be visualized in the form of various concepts; each of them corresponds to one studied factor or element from the set of regional statistical data.

The arrow, linking concepts C1 and C2 (Fig. 1), denotes the cause-and-effect relationship C1 —> C2 between them where C1 is the cause, C2 is the effect. These cause-and-effect relations are also called weighted arcs, w21 represents the degree of their influence.

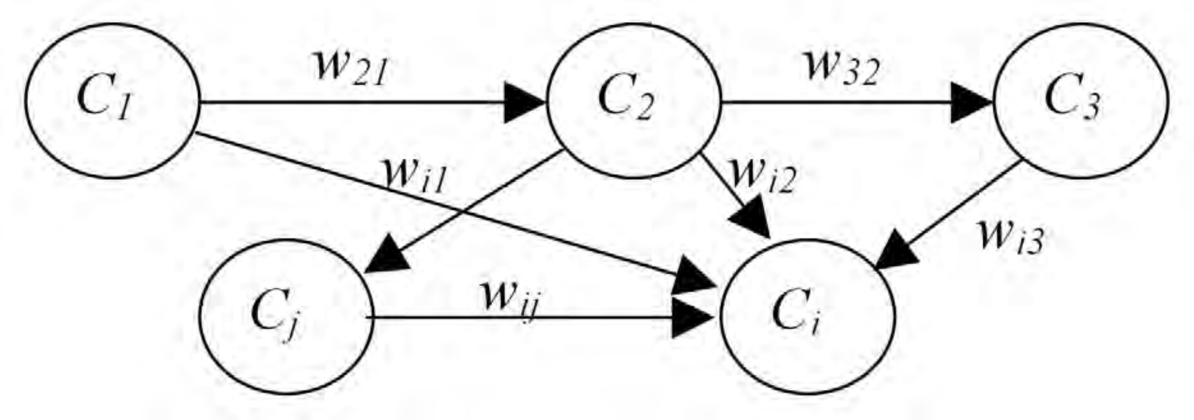

Figure 1: Fragment of a cognitive map.

The value of each modeling concept is defined at each step by means of calculating the impact of interrelated concepts on a certain concept by using the following equation:

$$A_i(t) = f\left(A_i(t-1) + \sum_{j=1}^{N} A_j(t-1) \cdot w_{ij}(t-1) \right). \tag{1}$$

where A_i *(t)* is the value of concept C_i at the time *t*, A_j *(t-1)* is the value of concept C_j at the time *t-1*, w_{ij} indicates the weight coefficient of the relationship between the concepts C_j and C_i; *f* - sigmoidal function. Usually, when weight values belong to the interval [-1, 1], this function is determined by the hyper-tangent equation:

$$f(x) = \frac{1-e^{-\lambda x}}{1+e^{-\lambda x}}, \tag{2}$$

where $\lambda > 0$ defines the steepness of the continuous function *f (x)*.

The relationship C_1 —> C_2 is called positive ($w_{21} > 0$), if the increment of C_1 leads to the increment (enhancement) of C_2, and decrease of C_1 leads to decrease of C_2; other conditions being equal.

The relationship is considered negative ($w_{21} < 0$) if the increment of C_1 leads to the decrease (breaking) of C_2 or vice versa, provided other conditions are equal.

If there is no relationship between the two concepts, then w_{21} will be equal to zero ($w_{21} = 0$).

All values of concepts and weight coefficients in FCMs have a fuzzy nature during representation of problems. After using the sigmoidal function, computed values of concepts after each modeling step will belong to the interval [-1, 1].

According to the FCM learning methodology provided by Papageorgiou (2004) experts design and develop fuzzy graph structure of FCMs, comprising concept nodes, which represent key principles, functions and factors of the system's functioning. After that, they determine the order of concept training, values of weight coefficients w_{ij} and initial values of concepts A_i *(0)* at *i, j = 1, …, N,* where *N* is the number of FCM concepts.

At first, the same sequence of training was assigned to all concepts. In contrast to, training priority was determined by means of streamlining concepts using paired comparisons intended to determine certain concepts in other equations. Several iterations were held and during each iteration, the effect concept was assigned the number of iteration +1 provided the value of the cause concept exceeded the value of the effect concept. The final order was determined using the ordinal scale and the algorithm proposed by Saati (1993) with the view of considering the hierarchical structure of concept division into reference points and subsystems.

In this study, FCM training was conducted through the artificial intelligence element - neural network training using the methodology (Papageorgiou, Stylios and Groumpos, 2003), which provided 4 embedded loops:

1) Repetition *Pmax* times for graduation of difference occurring in the process of training or until the convergence requirement is met for all concepts during the comparison of their values before and after training:

$$\max\left|A_i(p)-A_i(p-1)\right|<\varepsilon \tag{3}$$

where $A_i(p), A_i(p-1)$ present values of concepts at each current and previous step in the external training cycle.

2) 7 training sessions according to the hierarchical FCM structure with regard to the principle: input concepts are trained before the resulting concept;

3) Repetition of training up to *Cmax* times or until the convergence requirement (3) is met for the group of concepts related to the current session.

$$\max\left|A_i(t)-A_i(t-1)\right|<\varepsilon\ ; \tag{4}$$

where $A_i(t), A_i(t-1)$ present values of concepts during current and previous sessions.

4) training during current session in mutually perpendicular directions at *j = 1,…, N* according to the equation:

$$w_{ij}(t)=f\Big((1-\gamma)\cdot w_{ij}(t-1)+\eta\cdot A_j(t-1)\cdot\big(A_i(t-1)-w_{ij}(t-1)\cdot A_j(t-1)\big)\Big) \tag{5}$$

where η and γ – parameters of training speed which present small positive diminishing numbers depending on iteration number *c*:

$$\eta=b_1\cdot e^{-\lambda_1 c},\ \gamma=b_2\cdot e^{-\lambda_2 c} \tag{6}$$

Depending on positive constants b_1, λ_1, b_2, λ_2, which were determined by the trial-and-error depending on the convergence of weight coefficient values and the end of the training process. According to (Papageorgiou et al. 2003b), in this study the following values were set: $b_1=0.02$, $\lambda_1=0.1$, $b_2=0.04$, $\lambda_2=1$, $\varepsilon=0.001$.

Results

In this case, concepts are presented by statistical indicators of the Kazakh public authorities, or by parameters calculated on their basis by using well-known formulas. As regards the structure of interconnections, concepts are divided into two groups: dependent and independent.

The independent concepts (cause concepts) were used for situation modeling (defining impulses).

Dependent concepts (effect concepts) are objects of the Hebb (1949) learning rule, where each concept plays a role of single neuron consisting of at least two input concepts and at least one output concept. They can be cause concepts or input concepts in another neuron.

Roberts (1986) believed that the studied problem could be fully described by seven factors. However, development of computer technologies made it possible to consider a large number of factors. In this case, 252 concepts were considered and there is more to come. Cloud data storage technology was created, with unlimited nesting depth. In the future, all of them can be used as FCM concepts. Their number is determined as required, therefore, it is a fuzzy number.

According to the approach developed by Bossel at the International Institute for Sustainable Development (Kosko, 1993; Papageprgiou and Salmeron, 2011), the concepts were conventionally divided into seven basic reference points: Existence; Efficiency; Discretion; Safety; Adaptability; Co-Existence; Need.

According to the UN Millennium Declaration (Zabolotski, Tikhonin and Polyakova, 2008), the concepts were divided into 3 subsystems: economic, social, and the environmental one. Relevant codes of these concepts start with letters ‘x’, ‘y’, and ‘z’ (Table 1).

Pursuant to the research method, the initial values of concepts were determined by the initial tendency of concept development (Papageprgiou and Salmeron, 2011).

Table 1: Fragment of FCM Concept Database.

Concept Name	Value in 2013	Initial Trend	Codes
GRP, mln. tenge	34140040	0.1753	x1
Factory output, mln. tenge	17833994	0.1614	x2
Mining industry and quarry development, mln. tenge	10696926	0.1734	x3
Processing industry, mln. tenge	5852591	0.1420	x4
Electric power supply, gas supply, vapor supply and air conditioning, mln. tenge	1119063	0.1541	x5
Water supply, sewerage system, control over collection and distribution of wastes, mln. tenge	165412	0.1600	x6
Water collection, treatment and distribution, mln. tenge	77186	0.1448	x7
Sewerage system, mln. tenge	21903	0.1962	x8
Collection, processing and recycling of wastes, mln. tenge	59399	0.1609	x9
Gross agricultural production, mln. tenge	2386103	0.1298	x10
Amount of services rendered, mln. tenge	4305804	0.1715	x11
Executed construction works, mln. tenge	2439390	0.1220	x12

In this study, results of the correlation-regression analysis of concept development was set as the initial development trend (Fig. 2):

$$A_i = \frac{B_i}{S_i} \tag{7}$$

where B_i – coefficient of the linear regression equation; S_i – mean value of concept statistical data obtained between 2000 and 2013. This period may be altered on demand (for example, in the last 5 years: 2011-2015) or the trend value can be updated annually with regard to the statistical data updates.

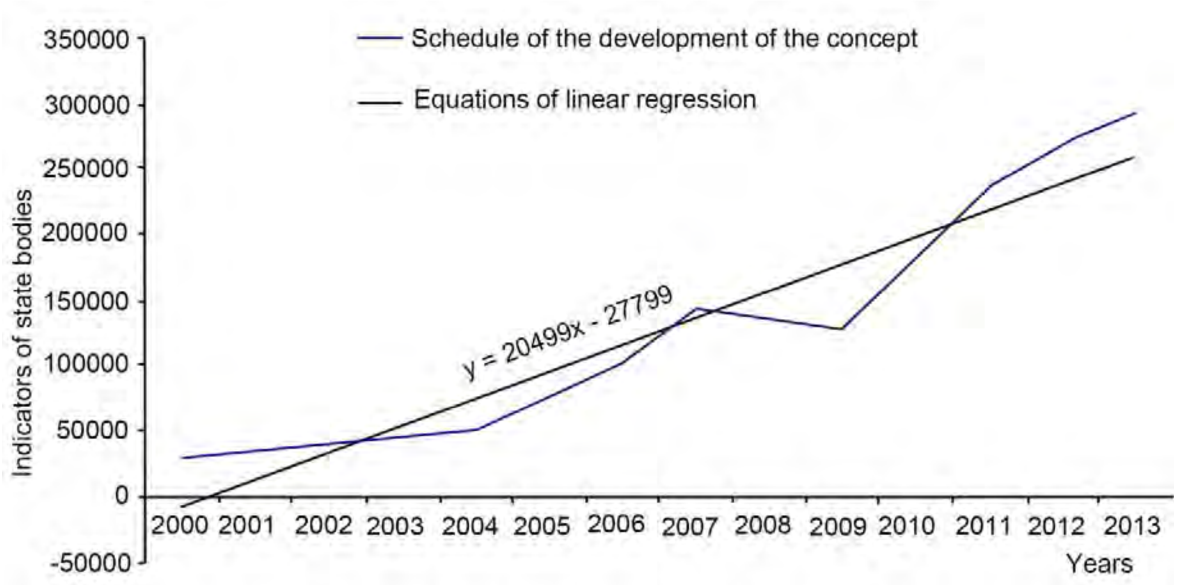

Figure 2: Concept development graph and its linear trend.

During the training process, only the initially set FCM weight values (not equal to zero) are updated. The computed weight values kept their initial signs and directions, as proposed by experts.

The iteration of the training process was stopped when two proposed criteria (3) and (4) were simultaneously met.

Figure 3 shows graphs, which demonstrate changes in concept values in the course of training from the third to the thirty-fourth iteration. The values of concepts underwent significant changes, up to the change of their sign.

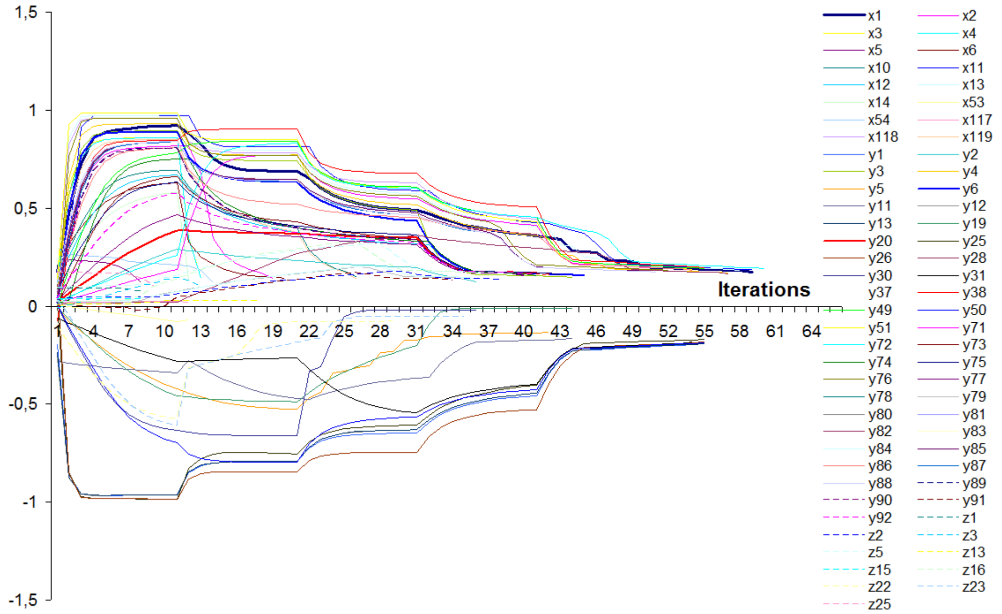

Figure 3: Changes of concept values in the course of training.

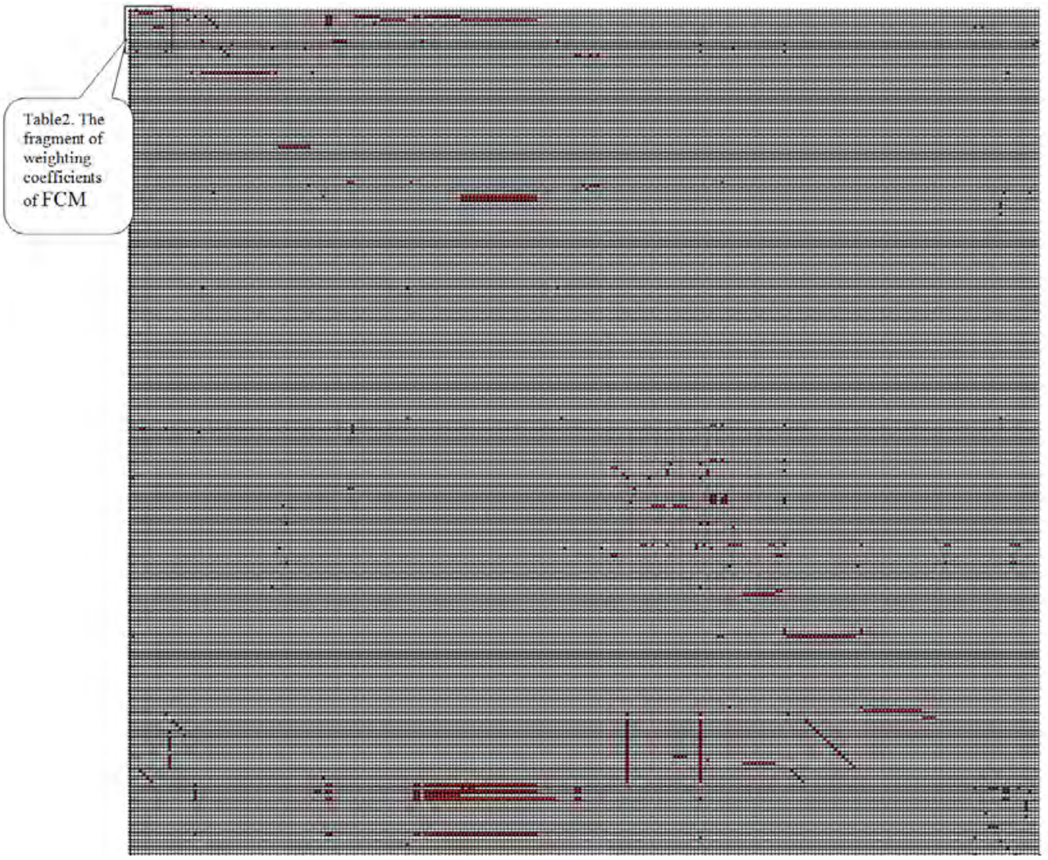

Figure 4: Configuration of none-zero matrix elements.

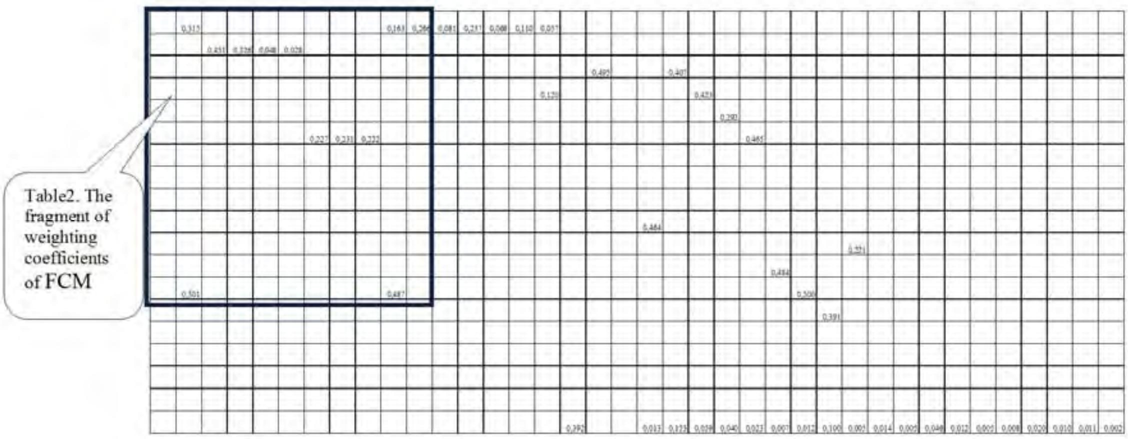

Figure 5: Magnified onfiguration of FCM none-zero matrix elements.

Table 2 shows a fragment of the FCM weight coefficients (13x10), and Figures 4 and 5 display magnified configuration of none-zero matrix elements of FCM weight coefficients after training. Figure 3 shows that the matrix is diffused.

Table 2: Fragment of FCM weight coefficients.

Concept Name	Codes	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
GRP, mln. tenge	x1		0.315								0.164
Factory output, mln. tenge	x2			0.452	0.326	0.048	0.03				
Mining industry and quarry development, mln. tenge	x3										
Processing industry, mln. tenge	x4										
Water supply, gas supply, mln. tenge	x5										
Water supply, mln. tenge	x6							0.227	0.23	0.228	
Water collection and treatment, mln. tenge	x7										
Sewerage system, mln. tenge	x8										
Collection, processing and recycling of wastes, mln. tenge	x9										
Gross agricultural production, mln. tenge	x10										
Amount of services rendered, mln. tenge	x11										
Executed construction works, mln. tenge	x12										
Trading volume, mln. tenge	x13		0.502								0.488

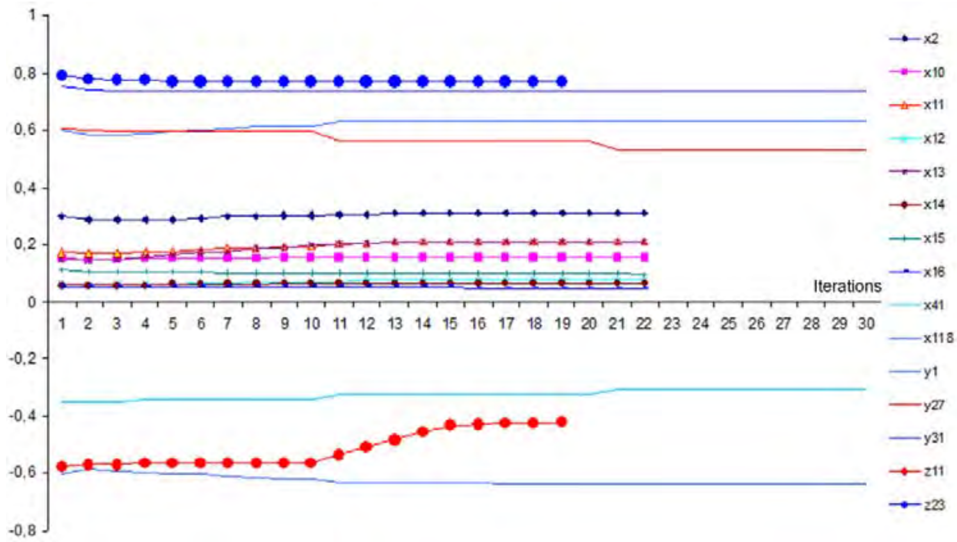

Figure 6: Graphs of changes in weight coefficients during training.

Figure 6 shows graphs of changes in weight coefficients of the concepts:
x1: Gross Regional Product (GRP, mln. tenge), 22 iterations;
y26: Crime rate, 30 iterations;

z22: Proportion of potable water samples, which do not comply with standards, %, 19 iterations.

Discussion

Simulation modeling or taking control actions to solve the problem demands setting the impulse values for independent concepts at the time moment t=0. This forecast results in obtaining the vector of factor values at the time moment t. Taking into account dynamics of key reference points in case of absence (self-development) and presence of external control actions (situation), one can assess the efficiency of relevant control actions.

Table 3: Setting FCM Impulses.

Factor Name	Factor Symbol	Factor Value	Impulse	Impulse, %
Investment into capital assets in arts, entertainment and recreation, mln. tenge	x37	8766	131.49	1.5
Simultaneous capacity of tourist facilities, number of guest nights	z28	5564	222.56	0.4
Investment into construction, mln. tenge	x25	3187	159.4	1.5
Investment into fixed assets related to accommodation and catering services, mln. tenge	x28	3934	59.01	1.5
Investment into other services, mln. tenge	x38	626	3.13	0.5

Practical demonstration of the developed tools is carried out through simulation modeling by the example of implementing the project aiming at tourism development on the Alacol Lake shore in Almaty region (Table 3), keeping in mind the following parameters of controlling actions (impulses):

- Increase in expenditures connected with capital assets referring to cultural and entertainment activities was determined by factor x37 (investment into capital assets related to arts, entertainment and recreation) and made 131.49 mln. tenge or 1.5% as compared to 8766 mln. tenge in the region in 2013;
- Increase in construction investments by the factor x25, made 159.4 mln. tenge or 1.5% as compared to 3187 mln. tenge in the region in 2013;
- Increase of investment into capital assets related to accommodation and catering services was determined by the factor x28 and amounted to 59.01 mln. tenge or 1.5% of the general regional value, 3934 mln. tenge in 2013;
- Increase of investment into capital assets related to other services by the factor x38 made 3.13 mln. tenge or 0.5% of the general regional value, 626 mln. tenge in 2013;
- Increase in the number of guest nights related to tourist facilities in Almaty region made 222.56, or 4.0%, by the factor z28, as compared to 5564 guest nights (totally) in the region in 2013.
- Several factors had significant impact. Namely, this refers to the increase in the amount of executed construction works by 2.425%, the number of people engaged in construction industry (2.021%), the amount of services rendered (1.848%), GRP (0.758%), the number of people engaged in transactions related to real estate, arts, entertainment and recreation; the number of people engaged in health care, social services, education, in the financial and insurance activities, and in other services (0.6%, on average).

Assessment results of system stability parameters are presented in Table 4.

FCM of the project (Fig. 6) shows mutual influence of concepts.

The calculations showed that the above impulses intended for tourism development at the Alacol Lake coast in the Almaty region would influence the indicators specified in Table 5.

The model of tourism development on the Alacol Lake shore in Almaty region indicated that development of that territory would be improved by 0.089%. In this regard, its social subsystem in sustainable development would be improved by 0.19%, the economic subsystem would be improved by 0.28% through the increase in the trade volume, the expected natural population growth, increase in the human potential development, decrease in the number of people with income below poverty line. The environmental subsystem would be improved by 1.01% according to the sustainability coefficient.

Further, the authors of this research evaluated sustainability and balance coefficients of the entire system and its subsystems. Analyzing calculation of *ks* and *kf* coefficients shown in Table 4, one could observe increase in sustainability coefficients and decrease in the balance coefficients. The mean value of *ks* and *kf* coefficients in the analyzed scenario made 1.5583, which exceeds the self-development value by 0.09%.

Table 4: Assessment of system stability parameters, ks - sustainability coefficient, kf - balance coefficient.

Subsystems		Economy	Social sphere	Environment	System in General	Mean Value
Self-Development	*ks*	1.2503	1.1475	1.1199	1.1726	1.5569
	kf	1.9456	1.9579	1.92	1.9412	
Scenario	*ks*	1.2538	1.1497	1.1313	1.1783	1.5583
	kf	1.9439	1.9573	1.9135	1.9382	
Increase in Value	*ks*	0.28%	0.19%	1.01%	0.49%	0.089%
	kf	-0.09%	-0.03%	-0.34%	-0.15%	

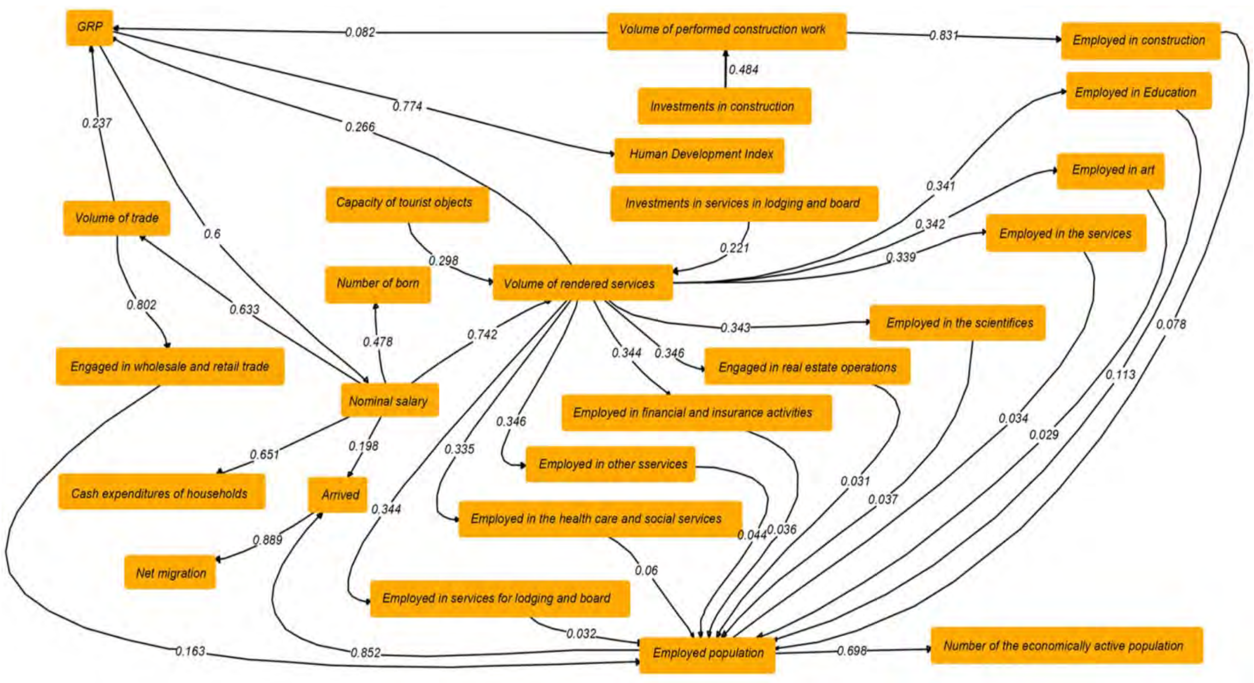

Figure 7: Cognitive map fragment of tourism development project in Almaty Region.

Table 5: Results of changes in trends and factors (not all changes are displayed).

Factor Name	Factor Type	Landmark	Symbol	Initial Trend	Situation Trend	Augmentation, %
Gross regional product	Economy	Existence	x1	0.18004	0.18762	0.758
Amount of services rendered	Economy	Existence	x11	0.20060	0.21908	1.848
Executed construction works	Economy	Existence	x12	0.17801	0.20227	2.425
Trading volume	Economy	Existence	x13	0.16220	0.16507	0.287
Investment into fixed assets	Economy	Efficiency	x19	0.19350	0.19409	0.059
Cash expenditures of households	Economy	Efficiency	x118	0.18437	0.18721	0.284
Total rate of natural increase	Economy	Coexistence	y3	0.10970	0.11122	0.151
Number of persons born	Economy	Need	y4	0.06505	0.06718	0.213
Human development index	Social Sphere	Efficiency	y6	0.02086	0.02653	0.566
Number of health care institutions	Social Sphere	Discretion	y19	0.00381	0.00391	0.01
Social tension index	Social Sphere	Safety	y25	0.00347	0.00526	0.179
Population size	Social Sphere	Existence	y28	0.02176	0.02193	0.017
Total area of commissioned residential buildings	Social Sphere	Adaptability	y37	0.15246	0.15257	0.011
Net migration	Social Sphere	Need	y38	0.00696	0.01096	0.401
Profit	Social Sphere	Need	y49	0.00762	0.01228	0.466
Nominal wages	Social Sphere	Coexistence	y51	0.15025	0.15463	0.439
Economically active population	Social Sphere	Discretion	y71	0.02850	0.03161	0.311
Employed population	Social Sphere	Discretion	y72	0.03404	0.03853	0.449
Employed in construction	Social Sphere	Discretion	y75	0.08515	0.10536	2.021
Engaged in wholesale and retail trade	Social Sphere	Discretion	y76	0.03129	0.03365	0.236
Employed in accommodation and catering services	Social Sphere	Discretion	y78	0.08799	0.09440	0.641
Employed in service	Social Sphere	Discretion	y83	-0.01466	-0.00833	0.632
Employed in healthcare	Social Sphere	Discretion	y86	0.02343	0.02966	0.623
Employed in arts	Social Sphere	Discretion	y87	0.04670	0.05305	0.635
Employed in other types of services	Social Sphere	Discretion	y88	0.18091	0.18735	0.643
Use of water for household needs	Ecology	Discretion	z16	0.02467	0.02479	0.011

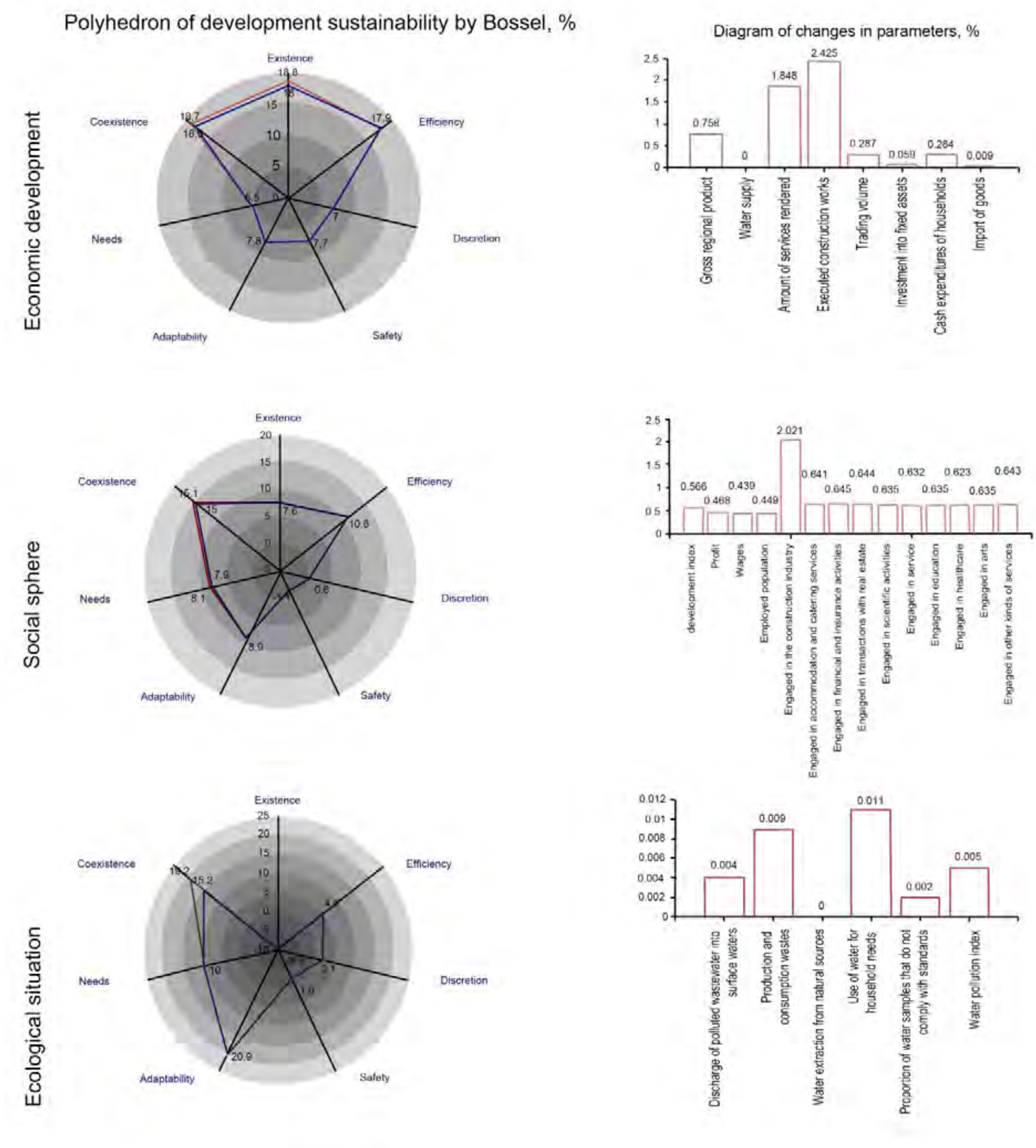

Figure 8: Reference points and concept change dynamics.

Thus, suggested measures imply a positive decision regarding tourism development in the Almaty region, which influence the general development of the region's territory: creation of additional jobs, increase in the amount of services rendered, increase in the gross regional product, increase in the regional human potential index, and other regional indicators.

Figure 8 shows the diagram of reference points and the dynamics of changes in concepts of this project based on relevant software and mathematical tools, which provide the possibility to describe complex systems of regional development with a view to promote decision-making.

Conclusion

The authors of this research proposed the cybernetic tool that could be used in:

- decision-making during planning and management of regional social and economic processes;
- situation modeling of putting into commission separate objects or elaboration of a strategic urban planning program for a specific region or the entire country.

Experts, analysts and developers of urban planning projects can use the proposed model in the elaboration of regional development strategies and programs.

Situation modeling was based on using FCM method under the fuzzy amount of regional data and fuzzy time horizon.

Keeping in mind fuzzy amount of data, this model provides the possibility to create original models of situations using the current and added concepts. The added concepts provide the required properties and database for at least three fuzzy time horizons.

The information received from the official public authorities for the last 14 years was considered as parameters (concepts) having impact on regional development.

Possible impact of each parameter on other regional indicators, including groups of social, economic and environmental parameters was analyzed by experts.

Fundamental interaction among concepts was determined upon studying the industrial, administrative, management and business relations.

The degree of mutual influence of concepts and their signs (positive or negative impact), was determined through a cybernetic algorithm in the process of FCM training.

Cognitive map training was based on the artificial intelligence element – the active Hebb learning rule. The impact of concepts was defined in the course of training. Fine adjustment of the fuzzy cognitive map was achieved by changing the training order using a rank scale and Saati's (1993) sorting algorithm.

The developed computer software was used in simulation modeling of regional socio-economic processes related to tourism development in Almaty region along with sustainable development and efficient administration of other regions.

Research results are presented in the form of a fuzzy cognitive map reflecting internal and external relations of the region, graphs reflecting development of socio-economic factors, and the Bossel (2010) criterion. Simulation of allocations lead to the expected result: GRP improvement, increase in employment and the environmental improvement.

Situation modeling can be used to assess the effectiveness of investment projects and state programs.

This approach can be used with regard to any object in any administrative-territorial entity, provided relevant statistical data.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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